Geothermal Energy Development Overview

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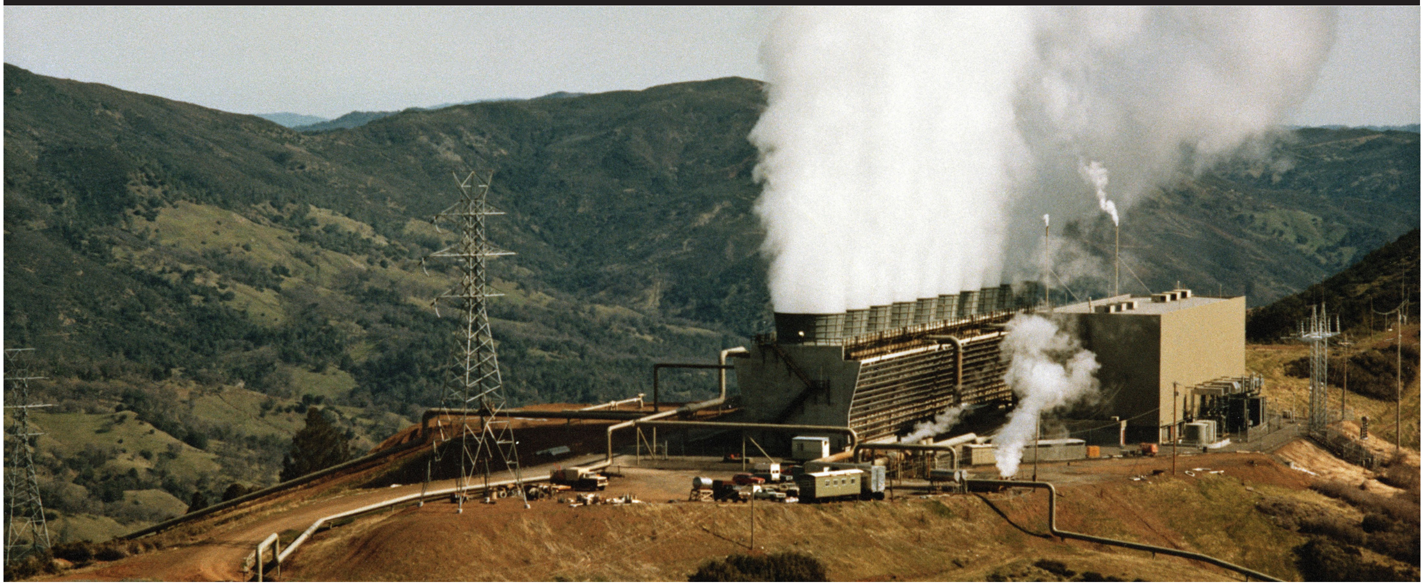

What is Geothermal Energy?

Geothermal energy is the natural heat found within the Earth. The temperature of the Earth increases with depth by 10-50° C/km. Scientists believe that about 80% of the heat comes from radioactive decay and about 20% from primordial heat associated with formation of the Earth. Geothermal waters differ chemically and physically from groundwater. Geothermal waters have a wide temperature range and may occur as steam. Hot water and steam are less viscous, more buoyant and flow more easily than cold water. Fluids warmed by this natural heat may be extracted and used to generate electricity, and provide heat for industrial processes and buildings. Worldwide, the largest use of geothermal energy is for electric power generation.

NREL Geothermal Energy Assessment

Maps of regional geothermal development potential have been developed from the 2001 Southern Methodist University Geothermal Laboratories continuous data set. The data used to produce the maps are derived from a model that incorporates heat flow, thermal gradient, sediment thickness, hot springs, and previous maps developed by the U.S. Department of Energy (DOE) and the University of Utah Research Institute (UURI). The data set was reclassified into discrete units, and adjustments were made to reflect the experience of expert geothermal reviewers from the Idaho National Engineering and Environmental Laboratory (INEEL), National Renewable Energy Laboratory (NREL), and Southern Methodist University (SMU).

Geothermal Energy Development Trends

Based on an NREL geothermal energy resource assessment and parks identified in the Geothermal Steam Act of 1970, as amended, 28 national park units are located within an area of excellent potential for the development of geothermal energy. Currently there are 2,734 megawatts (MW) of geothermal power plant electricity capacity installed in the western U.S. (www.EnergyAtlas.org).

Geothermal Energy Development

Geothermal resources can be classified as low-temperature (less than 90°C or 194°F), moderate-temperature (90°C - 150°C or 194 - 302°F), and high-temperature (greater than 150°C or 302°F). The temperature determines the method used to harness the energy. Some methods may have potentially adverse impacts on thermal features.

High Temperature Resources - are generally used only for electric power generation. Wells of varying depth (depending on the particular resource) tap steam and hot water to drive turbines that drive electric generators. In the U.S., three types of power plants are operating today:

· Dry steam plants directly use geothermal steam to turn turbines.

· Flash steam plants pull deep, high-pressure

Geothermal Energy Development (continued)

hot water into lower-pressure tanks and use the resulting flashed steam to drive turbines.
· Binary-cycle plants transfer heat from a moderately hot geothermal water to a secondary fluid with a much lower boiling point than water causing the secondary fluid to boil with the resulting vapor then driving the turbines.

Low- and Moderate-Temperature Resources - can be divided into two categories:
· Direct use - uses heat in water directly, over short distances, without a heat pump or power plant to heat buildings, industrial processes, greenhouses, aquaculture and resorts. Geothermal district heating systems supply heat by pumping geothermal water through a heat exchanger, which transfers the heat to water in separate pipes that is pumped into buildings. After passing through the heat exchanger, the geothermal water is injected back into the reservoir where it can be recharged and used again. Since this method extracts water it can impact geothermal features.

· **Geothermal heat pump system** - (also called a ground source heat pump) consists of: pipes buried in shallow ground near a building or inserted in a vertical well, a heat exchanger, and ductwork into the building. In winter, heat from warmer ground goes through the heat exchanger into the building. In summer, hot air is pulled through the heat exchanger into the relatively cooler ground. Heat removed during the summer can be used to heat water.

Impacts and Mitigation for Production Operations

Degradation of Thermal Features - Geothermal features such as geysers, fumaroles, hot springs, hot pools, mud pools, and sinter terraces may potentially be altered or destroyed by declining reservoir pressures as geothermal fluids reach the surface.
Mitigation: Reservoir decline can be mitigated by using appropriate discharge rates.

Changes in Ground Temperature - Geothermal development can alter the heat flow by the generation of steam. The generation and movement of steam can increase heat flow and ground temperatures stressing wildlife and vegetation.
Mitigation: Maintain reservoir pressures; experience suggests the areas of high heat flow and ground temperatures are usually localized, and they do not cause significant environmental problems.

Ground Subsidence - Fluid withdrawal reduces pore pressure in rocks resulting in compaction and surface subsidence. Subsidence may result in ground movement, building instability and instability of pipelines, drains, and well casings and impact surface and shallow groundwater systems.
Mitigation: Use of binary systems that return all geothermal fluid to the ground or recharging with treated wastewater can help mitigate subsidence.

Surface and Groundwater - Hot wastewater released directly into an existing natural waterway would adversely impact both aquatic and terrestrial plants and animals due to the high temperatures, and toxic substances such as lithium, boron, arsenic, hydrogen sulfide, mercury, and ammonia, increased erosion, precipitation of minerals such as silica, and shallow groundwater contamination.
Mitigation: reinject all waste liquid via injection wells. Binary plants typically have no releases.

Induced Seismicity - Geothermal development could theoretically increase the number of small earthquakes within the field caused by fluid reinjection.
Mitigation: reduce reinjection pressures to a minimum, and to ensure that all structures in the field are earthquake resistant.

Microclimatic Effects - As with any power plant, discharges of warm water vapor may affect the climate and vegetation near the power plant; increased fog, clouds, or rainfall.
Mitigation: design of the power station to minimize discharges and active monitoring and control of discharges when the plant is in operation. Air-cooled binary plants do not release any water vapor.

Hydrothermal Eruptions - In very active volcanic areas, hydrothermal eruptions are a potential hazard in high-temperature liquid-dominated geothermal fields. Eruptions occur when the steam pressure in near-surface aquifers exceeds the overlying rock pressure.
Mitigation: maintain reservoir pressures to minimize steam formation and heat-flow increases.

Impacts and Mitigation for Drilling Operations

Surface Impacts - construction and use of pipelines, access roads, well pads, generating facilities and cooling towers and associated noise, fumes, gases, dust, and visual impacts.
Mitigation - Reclamation of roads, well pads, mechanical mufflers and screens of vegetation. Use air-cooled and low profile equipment and proper selection of paint colors that match the surrounding environment.

Subsurface Impacts - mixing of thermal fluids with shallow aquifers possibly resulting in contamination with heat, mercury, sulfur, and other substances.
Mitigation: Maintain integrity of drill casing and use of proper drilling techniques.

Impacts to Thermal Features - fluids may migrate up fractures to the surface creating springs or fumaroles, contamination, "robbing" of fluids and vapors needed to maintain natural thermal features.
Mitigation: Maintain integrity of drill casing and use of proper drilling techniques.